Megatile Scanner Upgrade

Report by:
Thomas E. Beardsley

College of DuPage
425 Fawell Boulevard
Glen Ellyn, Illinois 60137

Mentored by:
Jim Freeman

Particle Physics Division
Fermi National Accelerator Laboratory
Batavia, Illinois 60510

Community College Internship (CCI) Program

August 8, 2015

Table of Contents

Abstract

Megatiles are large panels of scintillating material used in many particle detector projects, such as CMS HCAL. The Megatile Scanner is a two-axis machine that transports a radiation source to specified locations along a megatile and measures the current signal at each location. This tests each megatile for consistency and quality. The scanner had been decommissioned, but now has upgraded hardware, and a new controls system. After installing all new components and establishing communications to all new devices to the control computer, a LabVIEW program was created to perform a scanning sequence to test megatiles, and create documents to record data. An instruction manual was created detailing the upgrade process as well as how to use the program so that the process may be duplicated at different location in the future.

1. Introduction

1.1 Megatile Background

Scintillators are one of the most common materials used in devices for particle detection today. A scintillator is a material that emits light as ionizing radiation passes through it. Scintillating material are optimal for data collection in particle research because of some of the following specific features. A scintillator's light output is most often directly related to the energy of the incident radiation, providing the ability for the scintillator to act as radiation energy spectrometer. Scintillation detectors are also ideal because they have extremely fast response and recovery, allowing for the ability to collect precise timing information [1].

Particle detectors at Fermilab and the LHC are built in part using large tiles of plastic scintillating material, commonly referred to as megatiles. To give one example of modern employment, megatiles are used today in the CMS HCAL design, where they are utilized in measuring the timing and energy of hadronic showers, as well as their angle and position [2]. Specifically, the hadron barrel calorimeter consists of alternating layers of brass and scintillator tiles (Fig. 1), and the megatiles are read out with wavelength shifting fibers embedded in the megatiles themselves [2].

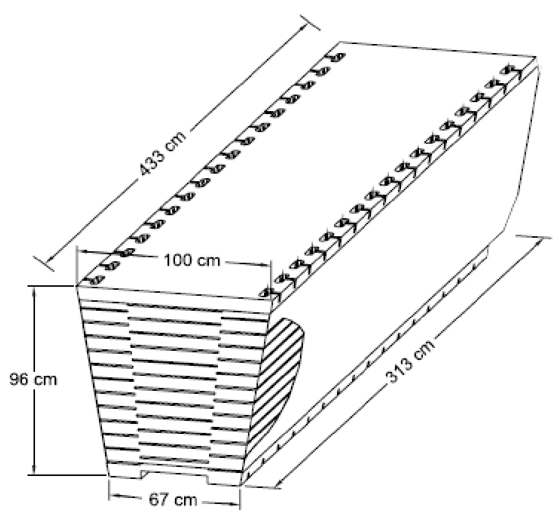


Fig. 1: Isometric view of an HB wedge, where scintillator trays (megatiles) are inserted in the slots on the end. [2]

1.2 Megatile Scanner Overview

A basic particle detection experiment setup using scintillator technology is called a scintillation detector, depicted in Fig. 2. A scintillation detector normally consists of scintillation material, a photomultiplier tube, and a current sensor. The radiation source excites the scintillator with ionizing radiation, then the light emitted is converted through the photomultiplier tube (PMT) to an electric current signal, which can be analyzed to gather energy and timing data with a DAQ device. [1]

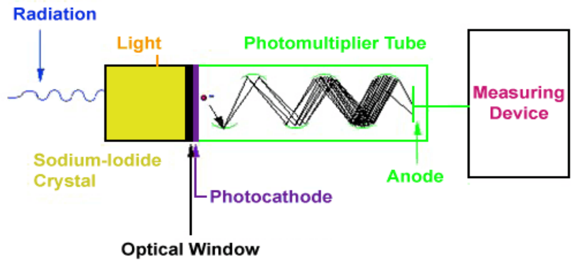


Fig. 2: Setup of a basic scintillator detector [3]

The Megatile Scanner is currently located at Lab 6 of Fermi National Accelerator Laboratory. The scanner utilizes this detector setup to analyze large panels of scintillating material (megatiles) examining different properties of the megatiles, including the magnitude of the light output, as well as the uniformity of each megatile. These megatiles need to be scanned before being employed in any sort of particle detector system, and this scanner acts as a tool to test the required properties and build quality of each megatile, making sure they are ready to be installed.

2. Methods

2.1 Initial Assessment

The Megatile Scanner had been used to test megatiles but was decommissioned over a decade ago. The Scanner was severely outdated and not functioning in its current state. The end goal of the upgrade project was to make the scanner fully operational again. After initial assessment it was clear that major hardware and software changes would need to be implemented in order to upgrade the scanner.

The first step in the upgrade process was to assess the current condition of the scanner and create a basis for documentation of the upgrade process. The scanner is a two-axis machine using two stepper motors and belt drive to transport a radiation source to specific locations along a megatile with precision. The scanner gathers current signal data at each location. Two motion controllers are used to control the motors, one per axis, and a system of limit and homing switches are used to control overall motion (Fig 2). An initial wiring diagram was created in AutoCAD Electrical to act as a basis for further upgrades, providing a better understanding of how the scanner operated. Upon inspection, it was clear there were missing or outdated components that needed to be replaced or created, including new motion controllers, a new DAQ device, and new control software.

2.2 Hardware and Setup

NOTE: Refer to Appendix B and C for block and connector diagrams, showing mechanical layout and wiring information.

The motors used to drive the belt system, moving the source platform, are Vexta PH296-E4.2 Stepper Motors. They are coupled with Dayton 19:1 Gear Reducers in order to provide the torque necessary to drive the system. The new controllers are MForce PowerDrive Motion Controllers from Schneider Electric (Fig 3). One function of each controller is to drive the stepper motors. The MForce is a microstepping driver, allowing for extreme precision in rotation of the motor. Unlike the old setup, these new motion controllers allow for the motion of the system to be controlled entirely through the controllers, including driving the motor, but also setting up limit and homing switches. The controllers utilize an I/O bank so that an input, such as a limit switch, can be wired to the I/O and programmed to whatever settings the user defines (limit (-), limit (+), home, etc.) This feature allows for a much simpler wiring setup, with all motion components being wired directly to the controllers, so only communication and power, as well as light and motion interlocks, are wired out to the patch panel located on the side of the scanner.

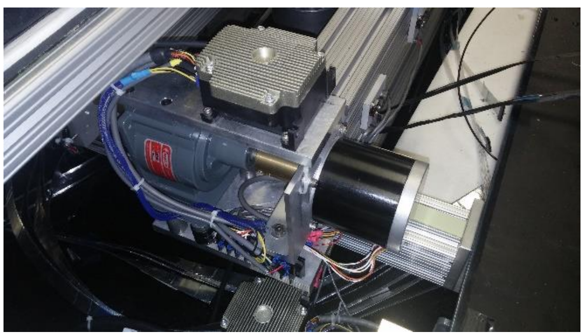


Fig. 3: Setup of the MForce PowerDrive Motion Controller, Vexta PH296-E4.2 Stepper Motor, and Dayton 19:1 Gear Reducer that controls the X-axis of the scanner

A control computer operates the motion of the scanner via RS-422 serial to USB communication with each motion controller. The new DAQ device is a Keithley 6487 Picoammeter/Voltage Source, and it is operated by the control computer via RS-232 serial to USB communication. The device is primarily used to take current signal readings at each position after a move during a scan sequence. The method by which the motion controllers and DAQ device are controlled and commanded is explained in section 2.3.

With the scanner utilizing a PMT as part of the DAQ system, removal of all light inside the scanner box is required. There are two doors on the scanner box to provide access to the megatile tray and the controllers. One is a long door opening up almost the entire (Y)-axis side wall on the (+X) axis side, and the other is located on the top of the box along the (-Y)-axis. Light interlock switches are placed on the doors and the megatile tray and are wired in series to the patch panel, so that if they are opened, the PMT and DAQ are shut off. There are also four additional motion interlock switches, one on each the ends of each axis, also wired in series to the patch panel, used to cut power to the motion. Both of these features were installed to protect system equipment.

2.3 Scanning Program: Overview

After installing all the new hardware, the next stage of the upgrade was to test each individual component for functionality and communication. It was first ensured that all new componenets were wire properly and were receiving power. Then, communications were tested using direct commands sent to the DAQ device and the MForce controllers via serial terminals on the control computer. The Keithley DAQ device was tested with Termite, a free terminal, using common SCPI commands as well as commands specific to the device (all commands available to the device are outlined in the Keithley 6487 reference manual). The controllers were tested with SEM Terminal, provided by Schneider Electric, using MCode commands, a language used to send commands specifically to Schneider Electric programmable controllers. Once communication was established, a scan program could be written to operate the machine.

The program was written in LabVIEW, a software program that uses visual programming and logical data flow. LabVIEW is commonly used in control systems and experiments such as this one. The overall objective of the program is to move the source to specific locations along the megatile, read out the current signal at the location, and repeat that process until the entire megatile has been scanned. A spreadsheet is generated so that the data can be analyzed. Fig. 4 provides a brief representation of the operation of the program.

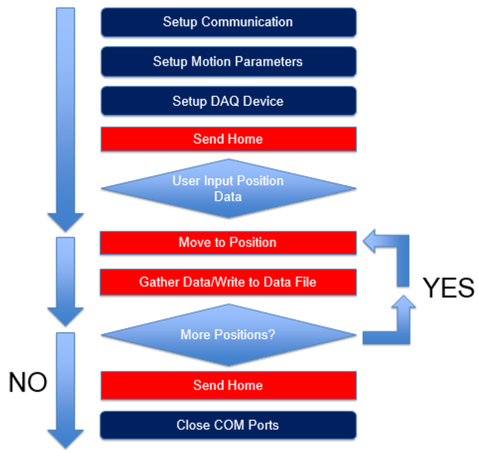


Fig. 4: Flow diagram of the operational structure of the LabVIEW scan program

2.4 Scanning Program: Detailed

NOTE: The following section explains in detail how the scanning program is structured and its operation. For simple instructions on how to use the program, as well as setup information, see Appendix A.

The program utilizes The Virtual Instrument Software Architecture API, or VISA. This software contains many functions for communicating to instruments and devices via serial. Each controller and the DAQ are assigned a COM port number when first installed on the control computer. The program first opens up a VISA session with each device, using the COM port number as the identifier. This session stays open until communication is terminated at the end of the scan run. Each command is sent using a VISA write command, and device status is determined using a VISA read command. The commands sent with VISA write are simply the textual commands (MCode and SCPI) used with the terminals. The LabVIEW software is mainly a tool to order and time events and commands.

After a VISA session is open with each controller and the DAQ device, communication settings are set to pre-programmed values. Motion (acceleration, microstepping resolution, etc.) and limit (homing and limit switches) settings are then set for the controllers, as well as the DAQ settings (measurement filtering, source voltage, etc). The program then sends the source platform home (each axis to the home switch), and zeros the position of the stepper motors. The program is then paused and the user is instructed to specify a file or create a file to which the data from the scan will be written, and input the position values (X and Y coordinates) for the scan into the position spreadsheet file (Pos Data.csv) in centimeters. The program must read and write from comma delimited files. The program then takes each coordinate one at a time and converts them to step values for the motor, and gives an absolute move command

(Fig. 5) to the motors to move to that coordinate. Once the source platform arrives, the motion is paused, and the DAQ device takes five filtered current signal readings at that location. Each current reading is then written to the selected spreadsheet file, and a row of data is recorded, including: date and time, the current signal value, the X position, and the Y position. Therefore, five data sets are created per position. This process is then repeated for all coordinates in the position file, with the last readings being taken at the home position. The program then ends, prompts the user to press the stop button, and terminates the serial connections. The data file can then be opened and the entire data set for the megatile can be viewed and analyzed.

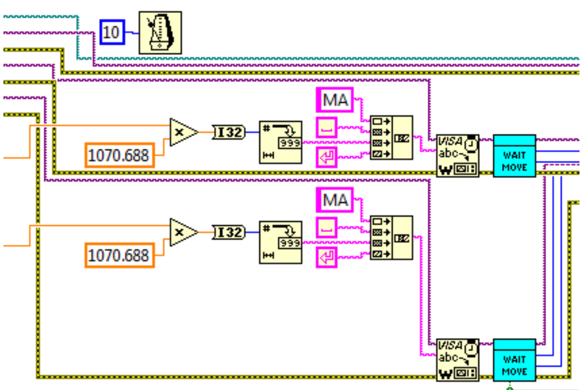


Fig. 5: Section of the LabVIEW code. Shows the program converting the position values into steps and writing absolute move commands to the controllers.

The program has features focused on equipment safety as well. The limit switches and the tray switch, after being set at the beginning of the program run, automatically stop all motion in the direction of the limit switch when they are tripped. When this occurs, the user is notified with simulated lit LEDs on the front panel. A stop button is also placed in the front panel, and may be pressed at any time to stop all motion and terminate the program. The front panel is LabVIEW's user interface. For the scan program, every setting is preset except for the COM ports and the file paths, seen in Fig. 6.

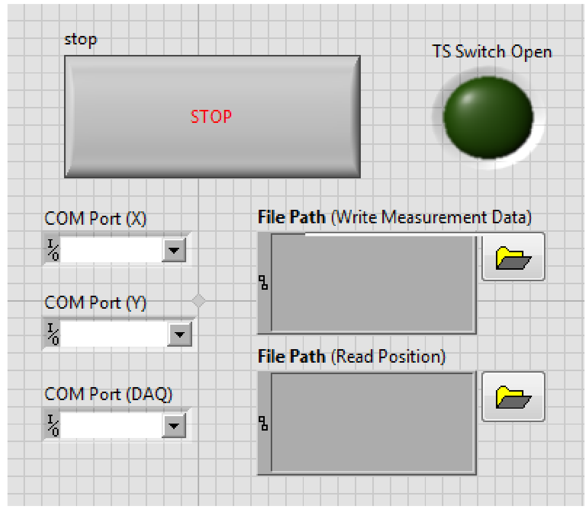


Fig. 6: Front panel of the LabVIEW scan program

3. Impact/Future

As of completion of this report, the scanning program is fully functional, including operation of all motion and the DAQ. The next phase of the upgrade process is installation of a PMT and optical cables to transport the light emitted by the megatiles, so that testing of the scanner with a radiation source can begin. Once the scanner passes those tests, it will be fully operational and ready to be used. Further documentation of this upgrade includes; a wiring diagram of the new electrical setup, a manual outlining the scanner's operations, as well as a step-by-step guide of the upgrade process (Appendix A). This report, along with the other documentation, will allow for simpler and more efficient setup and operation of the Megatile Scanner. It is still to be determined whether the scanner will be relocated to be used at CERN, or if the entire upgraded machine will be replicated there, or a different facility. With this program and documentation, either of these options are viable and can be performed in a much more timely and inexpensive manner.

4. Acknowledgements

This project was conducted at Lab 6 of Fermi National Accelerator Laboratory with the assistance of Bill Hefler, Jerry Zimmerman, Jim Freeman, and Tanja Waltrip. Bill Hefler and All Control provided testing kits and technical support for the new control hardware, which was a huge help in the early stages of the project. Jerry's technical expertise and experience were invaluable during the installation of the new hardware and wiring stages. Jim's excellent supervision and mentoring created a working environment that encouraged learning and progress. As coordinator for interns at Fermilab, Tanja was a wonderful resource for everything non-project related, and was invaluable during the internship. All work was performed under the Department of Education Community College Internship (CCI) Program.

References

[1] Leo, William R. Techniques for Nuclear and Particle Physics Experiments. Berlin: Springer-Verlag, 1987. Print.

[2] CMS-HCAL Collaboration. "Design, performance, and calibration of CMS hadron-barrel calorimeter wedges." European Physical Journal C.55 (2008): 159-71. Print.

[3] "Introduction to Radiation Detectors." Equipco. Equipco Rentals, n.d. Web. 27 July 2015. [Fig 1.]

Appendix A:

Megatile Scanner Manual

Setup and User Instruction

By: Thomas Beardsley

Fermi National Accelerator Laboratory

Table of Contents

CAUTION: HOT PLUGGING!

Do not connect or disconnect any power or communications while the MForce PowerDrive Motion Controllers or the Keithley 6487 Picoammeter/Voltage Source are in a powered state.

Remove DC power by powering down on the AC side of the DC power supply.

1. Introduction

This guide will provide quick and efficient instruction in setting up and running the Megatile Scanner. The scanner is a two-axis machine that transports a source platform to preset locations via belt drive to collect current signal readings, scanning an entire megatile and creating a report containing the data set for the entire megatile.

NOTE: This manual will only provide necessary information to setup and run the scanner. For more detailed information on the upgrade process and how the scanning program works, see the **Megatile Scanner Upgrade** *report included in the Setup Package.*

1.1 System Components

The scanner motion system is comprised of these components:

- Vexta PH296-E4.2 Stepper Motor x2
- Dayton 19:1 Gear Reducer x2
- MForce PowerDrive Motion Controller x2
- IMS MD-CC4 RS 422/485 to USB Cable x2
- Mechanical Switches x14

There are two soft switches per axis acting as positive and negative limits. There are two motion interlock switches per axis acting as power shut-offs in case of limit switch malfunction. There are three light interlock switches (on access doors) and one tray switch acting as a detector system shut-off in case of light exposure from open doors or tray movement. The tray switch also acts as a motion stop to protect the mechanical system in case of tray movement.

The data acquisition (DAQ) system is comprised of these components:

- Keithley 6487 Picoammeter/Voltage Source x1
- Keyspan 19HS RS 232 to USB Adapter Cable x1

The electrical system is comprised of these components:

- Wiring (including pre-made connector cables from the MForce PowerDrive Quick Start Kits)
- Patch Panel (output interface) x1
    - DE-9 Serial Interface x2
    - Power Interface x2

- Light Interlock Interface x2
- Motion Interlock Interface x2

- Control Computer (PC-Windows 7 64-bit OS) x1
- HP 6227B Dual DC Power Supply (25 Volt) x1

(Future Installment) The detector system is comprised of these components:

- Photomultiplier Tube x1
- Optical Cable Unknown Length
- Optical Connectors Unknown Number
- Radiation Source Platform and Housing

1.2 Megatile Scanner Setup Package

Included in the Megatile Scanner Setup Package is everything needed to setup and run the Megatile Scanner. For additional help with system components or additional downloads visit the following websites:

- http://motion.schneiderelectric.com/products/mforce_powerdrive_mfi.html
- http://www.keithley.com/products/dcac/voltagesource/application/?mn=6487

The following reference manuals from the manufacturers are included:

- Keithley 6487 Manual
- Keithley 6487 Reference
- MCode Programming and Software Manual
- MForce Motion Controller Manual
- MForce Motion Controller Reference
- MForce PowerDrive Connectors Reference
- Stepping Motor PH296 Manual

The following electrical diagrams are included. They are both .dwg files created in AutoCAD Electrical:

- Block Diagram (shows all electrical components with relative positions and connection points)
- Connector Diagram (shows all connectors and pins with each specific wired connection)

The following serial terminals are provided to aid in troubleshooting communication and system component malfunction:

- MCode Terminal (used to send MCode commands to the MForce PowerDrive Motion Controllers)
- Termite Terminal (used to send SCPI commands to the Keithley DAQ device)

The Spreadsheet Files folder is used as a location to save and create comma delimited files (.csv).

- Location to save data files created from scan runs
- Contains a pre-made position data file ready to receive user data (Pos Data.csv)

The scanning program is included and ready to be run. The program was written in LabVIEW 14.0.

- The program will executed from the front panel of MAIN_SCAN.vi
- The SubVIs folder contains all the SubVIs utilized in the main vi

2. Setup

2.1 Hardware Installation

Once the mechanical system is completely setup, including switches, the pulley drive, the motors and gear reducers, and the box with access doors itself, the next step is to install the hardware components and wire them. The (Y) MForce controller is fastened in its position on the base of the box next to the motor. The (X) MForce controller is fastened in its position on the platform of the X-axis, above the motor. The power supply, Keithley DAQ device, and control computer are all placed outside the box next to the patch panel.

For wiring information, please refer to the block and connector electrical diagrams included in the Megatile Scanner Setup Package.

2.2 Serial Communication

NOTE: The Megatile Scanner system was developed on Windows 7 64-bit OS, and has only been tested in that environment. See the following website for more information and cable drivers:

- http://motion.schneider-electric.com/downloads/cable_drivers.html

Serial Connection Note:

PLUG SERIAL TO USB CABLES INTO THE PC ONE AT A TIME

If the recommended serial to USB cables are used (see section 1.1), the cable drivers will be automatically installed onto the PC. Each cable/device will be assigned a COM port number, and that number reference will be saved onto the PC. Disconnecting and reconnecting the serial cable to a different USB port on the PC will not change the COM port number for that device. As each cable is plugged in, Record the COM port number for each device, as they will be used as reference in the scan program. The COM port numbers can be viewed here:

Computer > System Properties > Device Manager > Ports

How to check serial communication to:

1. MForce PowerDrive Motion Controller
    a. Power on controllers
    b. Launch SEM Terminal.exe
    c. Click View and select New Terminal
    d. In Terminal1, double click on the pane in the lower right hand corner that displays the COM port and baud rate (opens terminal settings
    e. In Communication Settings, select the correct port number for the controller being tested, leave the baud rate at 9600, and select MDI for device, then click Set
    f. Double click “Port Closed” on the bottom of the terminal screen to open the COM port
    g. With the cursor in that terminal, press control^C (hold down control + C). This sends a command to restart the controller.
    h. If successful, the terminal will display a message similar to: “Copyright 2010 Schneider Electric Motion USA”

   i. MAKE SURE TO CLOSE THE PORT WHEN FINISHED. Leaving it open will cause errors in running the scanning program. Do this by double clicking “Port Open”

2. Keithely 6487
   a. On the front panel of the Keithley device press the “config/local” button
   b. Press “COMM”
   c. Scroll down until “TX TERM:” appears
   d. Scroll to “CRLF” and press “ENTER”
   e. Press “EXIT”
   f. Run Termite.exe on the control PC
   g. Click “settings”
   h. Select the correct port number for the DAQ device from the drop down menu
   i. Under “Transmitted text” select “Append CR-LF”
   j. Click OK
   k. Type “:*IDN?” and press Enter
   l. The terminal will respond with the name of the device if communicating correctly
   m. MAKE SURE TO CLOSE THE PORT WHEN FINISHED. Do this by clicking on the COM number.

Leaving it open will cause errors in running the scanning program. Do this by clicking the button where the COM number is displayed

If you receive VISA errors during scan program execution, the COM port may be open to one of the devices. These terminals may be used to close the ports.

Refer to the reference manuals for the Keithley DAQ device or MCode to send other direct commands using these terminals for further testing.

2.3 Software Installation

The following software must be installed on the control PC to run the scan program:

- LabVIEW 14.0
  - The program was developed in this version. If previous versions are being used, the VIs may be converted to run in that version)
- NI-VISA Drivers
  - These drivers may be found at this website:

- http://www.ni.com/nisearch/app/main/p/bot/no/ap/tech/lang/en/pg/1/sn/catnav:du,n8:3.25.123.1640,ssnav:ndr/

3. Scanning Program

3.1 Pre-Scan Setup

NOTE: Make sure the tray is pushed all the way in, activating the Tray Switch, or there will be program run errors.

Once all the software is installed, and a megatile is in place and ready to be scanned, there are a few steps that need to be performed before the program is opened:

1. First, in the Megatile Scanner Setup Package folder, open the Data File folder
2. Open Pos Data.csv
3. Input X and Y positions (in cm) under their respective columns, creating coordinate positions

   NOTE: The program uses absolute moves, or moves the source platform to positions relative to the 0, or home, position. So, when inputting pos data, each coordinate should be a position relative to (0,0), in a sequence down the column.

4. Save the file and exit

The program is now ready to be set from inside LabVIEW:

1. Under the Scan Program folder, open MAIN_SCAN.vi
2. Click Launch LabVIEW

This will open up the Front Panel of the scan program.

3. If the devices are connected properly and communicating, each COM Port drop down menu will display all the COM port numbers of all the available devices. Select the COM port number on the front panel that corresponds to the correct device (ex. under COM Port (X), select the number for the MForce controller operating the X-axis motor)

4. In the File Path (Read Position) window, input the file path of the Pos Data.csv file OR click on the file icon and navigate to the file and select

3.2 Scan Program Operation

The program is now set and ready to be run. Follow these steps to operate the scan program:

1. Ensure all devices are powered ON
2. Click the Run button, the white arrow icon located in the top left corner of the front panel
3. The program will set parameters for all devices. Click "OK" to move the source platform to the home position
4. Make sure the position data is correct and the Pos Data.csv file is closed. Click "OK"
5. Choose file to write. EITHER select a .csv file to write scan data to, OR enter a file name ending with ".csv" (ex. Megatile_1.csv) and Click "OK"
6. The scanning run will begin. Wait until the scan is complete.
7. Click "OK" in the dialog box, and then click the STOP button on the front panel

The data file is now available in the Data Files folder. The file will display the date/time, current signal reading, and X/Y position for each reading taken. The scanner takes five readings at each location. Each row represents one reading data set.

NOTE: If the program malfunctions, first try restarting the scan. Then try quitting out of LabVIEW and starting from step 1 before resorting to other troubleshooting options.

3.3 Stop Button and Indicators

The LED indicator on the front panel labeled "TS Switch Open" will be lit when the tray switch is deactivated, meaning the tray has moved out of position. If this occurs, push the tray all the way in, and restart the scan.

The STOP button on the front panel may be pressed at any time while the program is running. Pressing it will stop all motion and terminate program execution. In order to continue after a STOP, the scan must be started over at the beginning of the sequence (see section 3.2).

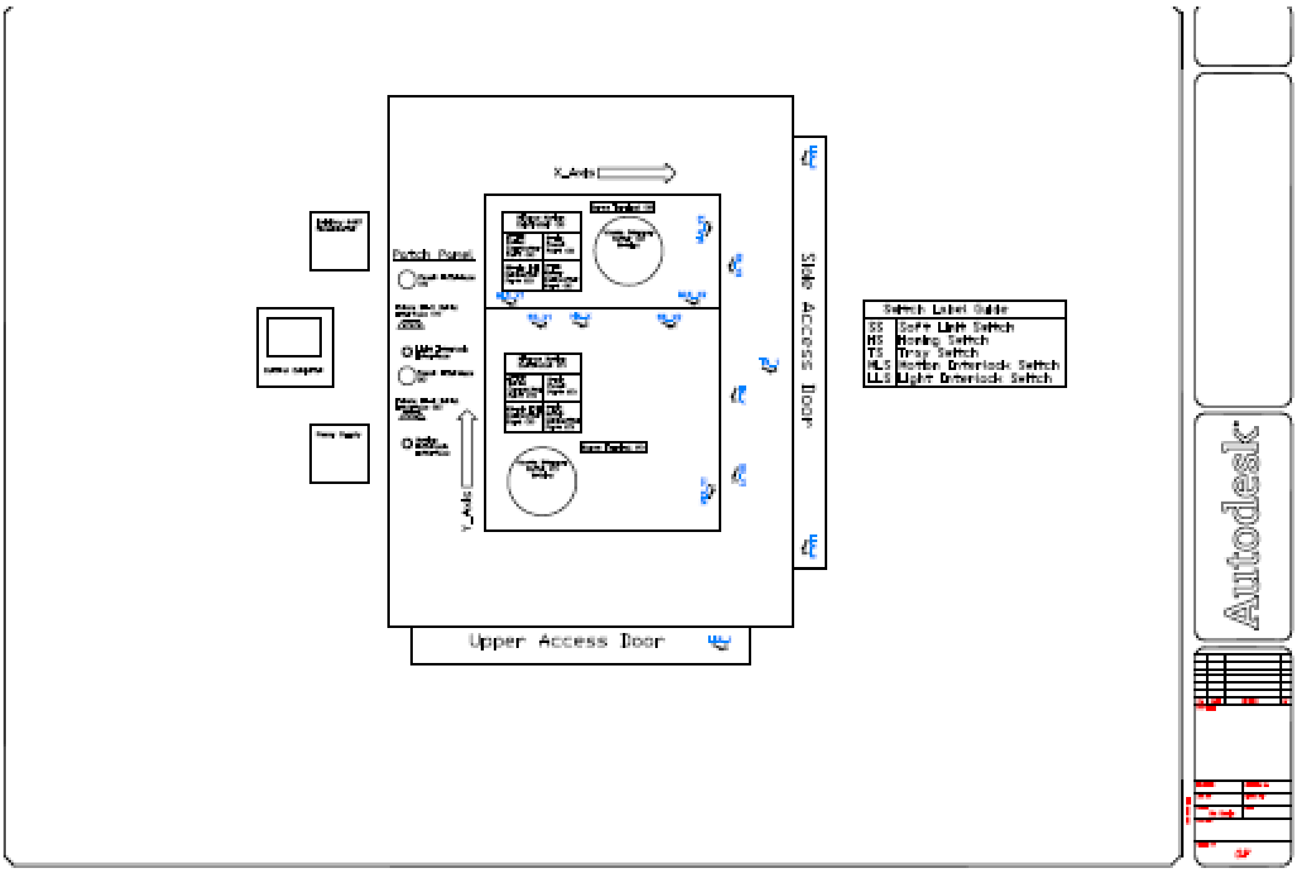
NOTE: If the STOP button is pressed during motion, the motion will stop and a dialog box will appear. Click “OK.” THE STOP BUTTON DOES NOT NEED TO BE PRESSED AGAIN. If the STOP button is pressed during DAQ, the DAQ device will finish taking its readings, and then the program will terminate, and the same procedure can be followed.

4. Support and Contact Information

For technical support regarding any of the hardware, contact the manufacturer or refer to the manuals. For support regarding the scan program or this instruction manual, use the following contact info:

Email: Te.beardsley@yahoo.com

Appendix B:


X_Axis
Y_Axis
Patch Panel
Side Access Door
Upper Access Door
Switch Label Guide
SS Soft Limit Switch
HS Homing Switch
TS Tray Switch
MLS
LLS Light Interlock Switch
Autodesk

Appendix C: